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Nanotechnology In Agriculture: A Perspective

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Abstract
Nanotechnology is one of the most useful technologies which contributes to the sustainable competitiveness and growth in several sectors of industry. The field of Nanotechnology has become a new source for key improvements in the field of agricultural sector and it has been engaging the researchers to account for the current challenges of sustainability, food security and climate changes. However, concrete contributions are still uncertain. Despite the numerous potential advantages of nanotechnology and the growing trends in publications and patents, agricultural applications have not yet made it to the market. Several factors could explain the scarcity of commercial applications. On the one hand, industry experts stress that agricultural nanotechnology does not demonstrate a sufficient economic return to counterbalance the high initial production investments. On the other hand, new nanotech regulation in the country might create regulatory uncertainty for products already on the market and affect public perception. However, recent studies demonstrate that public opinion is not negative towards nanotechnology and that the introduction on the market of nanotech products with clear benefits will likely drive consumer acceptance of more sensitive applications. The rapid progress of

nanotechnology in other key industries may over time be transferred to agricultural applications as well, and facilitate their development.

Introduction

Currently, the major challenges faced by world agriculture include changing climate, urbanization, sustainable use of natural resources and environmental issues like runoff and accumulation of pesticides and fertilizers. These problems are further intensified by an alarming increase in food demand that will be needed to feed an estimated population of 6–9 billion by 2050. Furthermore, the world's petroleum resources are decreasing; there will be an additional demand on agricultural production as agricultural products and materials will soon be viewed as the foundation of commerce and manufacturing. At one fell swoop, there are new opportunities emerging, e.g. generation of energy and electricity from agricultural waste but pending workable economics and encouraging policy. This above-mentioned scenario of a rapidly developing and complex agricultural system is existing and greater challenges will be posed to the developing countries as, in the developing countries, agriculture is the backbone of the national economy. They face many critical issues such as lack of new arable soil, reduction of the current agricultural land due to competing economic development activities, commodity dependence, poverty and malnutrition, which need to be solved on a sustainable basis. Profound structural changes in the agricultural sector have occurred due to the fast development of technological innovations, but these also pose challenges such as sustainable production considering food security, poverty reduction and public health improvement. For developing countries, advancement in science and technology can offer potential solutions for discovering value addition in their current production systems.

Many technologies have been developed that have the potential to increase farm productivity and also reduce the environmental and resource costs related with agricultural production. These technologies have the ability to conserve land and water by increasing yields through the application of the same or fewer inputs, ultimately conserving the environment. However, it will be very critical to support them, as these may not be commercially profitable and may also result in increase in the disparity between developing and developed countries. So their social and ethical implications should be considered. However, the need of the hour is to consider their efficiency in some fields, while these may not provide a solution to the existing problems associated with food production and its distribution round the world. Therefore, the developing countries should actively participate in research and development of these technologies while considering their ability to utilize these new technologies.

Nanotechnology for Crop Biotechnology

Chemists have successfully crafted three-dimensional molecular structures, a breakthrough that unites biotechnology and nanotechnology. They made DNA crystals by producing synthetic DNA sequences that can self-assemble into a series of three-dimensional triangle-like patterns. The DNA crystals have "sticky-ends" or small cohesive sequences that can attach to another molecule in an organized fashion. When multiple helices are attached through single-stranded sticky ends, there would be a lattice-like structure that extends in six different directions, forming a three-dimensional crystal. This technique could be applied in improving important crops by organizing and linking carbohydrates, lipids, proteins and nucleic acids to these crystals.

Nanoparticles can serve as 'magic bullets', containing herbicides, chemicals, or genes, which target particular plant parts to release their content. Nanocapsules can enable effective penetration of herbicides through cuticles and tissues, allowing slow and constant release of the active substances.

Chemists have utilized a 3-nm mesoporous silica nanoparticle (MSN) in delivering DNA and chemicals into isolated plant cells. MSNs are chemically coated and serve as containers for the genes delivered into the plants. The coating triggers the plant to take the particles through the cell walls, where the genes are inserted and activated in a precise and controlled manner, without any toxic side or after effects. This technique has been applied to introduce DNA successfully to tobacco and corn plants.

Nanoparticles and Recycling Agricultural Waste

Nanotechnology is also applied to prevent waste in agriculture, particularly in the cotton industry. When cotton is processed into fabric or garment, some of the cellulose or the fibers are discarded as waste or used for low-value products such as cotton balls, yarns and cotton batting. With the use of newly-developed solvents and a technique called electrospinning, scientists produce 100 nanometer-diameter fibers that can be used as a fertilizer or pesticide absorbent. These high-performance absorbents allow targeted application at desired time and location.

Ethanol production from maize feed stocks has increased the global price of maize in the past two years. Cellulosic feed stocks are now regarded as a viable option for biofuels production and nanotechnology can also enhance the performance of enzymes used in the conversion of cellulose into ethanol. Scientists are working on nano-engineered enzymes that will allow simple and cost-effective conversion of cellulose from waste plant parts into ethanol.

Rice husk, a rice-milling byproduct can be used as a source of renewable energy. When rice husk is burned into thermal energy or biofuel, a large amount of high-quality nanosilica is produced which can be further utilized in making other materials such as glass and concrete. Since there is a continuous source of rice husk, mass production of nanosilica through nanotechnology can alleviate the growing rice husk disposal concern.

Nanotech Delivery Systems for Pests, Nutrients, and Plant Hormones

Nanosensors and nano-based smart delivery systems could help in the efficient use of agricultural natural resources like water, nutrients and chemicals through precision farming. Through the use of nanomaterials and global positioning systems with satellite imaging of fields, farm managers could remotely detect crop pests or evidence of stress such as drought. Once pest or drought is detected, there would be automatic adjustment of pesticide applications or irrigation levels. Nanosensors dispersed in the field can also detect the presence of plant viruses and the level of soil nutrients. Nano encapsulated slow release fertilizers have also become a trend to save fertilizer consumption and to minimize environmental pollution.

Nanobarcodes and nanoprocessing could also be used to monitor the quality of agricultural produce. Scientists used the concept of grocery barcodes for cheap, efficient, rapid and easy decoding and detection of diseases. They produced microscopic probes or nanobarcodes that could tag multiple pathogens in a farm which can easily be detected using any fluorescent-based equipment. This project generally aims to develop a portable on-site detector which can be used by non-trained individuals.

Through nanotechnology, scientists are able to study plant's regulation of hormones such as auxin, which is responsible for root growth and seedling establishment. Scientists developed a nanosensor that reacts with auxin. This interaction generates an electrical signal which can be a basis for measuring auxin concentration at a particular point. The nanosensor oscillates, taking auxin concentration readings at various points of the root. A system of formulas then verifies if auxin is absorbed or released by the surrounding cells. This is a breakthrough in auxin research because it helps scientists understand how plant roots adapt to their environment, especially to marginal soils.

Green nanotechnology:

For sustainable development around the world, finding an inexpensive, safe and renewable source of energy is the need of the hour. Green nanotechnology has been developed for a flexible and efficient source of energy in the form of solar cells which have long been an ambition for tropical countries. However, the use of glass photovoltaic panels is delicate and too expensive. A high priority of research in most industrialized countries has been given to the development of photovoltaic panels, energy storage and other nanotechnology-enhanced solar-thermal energy conversion systems. Economic feasibility is the critical factor for developing these photocatalysts and energy materials and if we address this factor properly, we will be able to develop more and more 'out-of-box' ideas. A substantial technical breakthrough has been made and explored the use of photosynthesis protein units derived from leafy vegetables and plants for direct conversion of solar energy to electricity, and has remained functional for about one year. A glass microscope slide that serves as the cell base is the most expensive component of this system. Capturing solar energy will be a great achievement that will serve humanity and is likely be persistent and intensified in the years ahead.

Nanotechnology is also helpful for the conversion of biomass into fuels, chemical intermediates, specialty chemicals and products including catalysts in order to reduce production cost while being economically feasible. These nano structured catalysts have large surface area per unit volume and are capable of having precisely controlled composition, structure functionalization and other important properties of catalysts.

Conclusion and perspectives

Nanotechnology has great potential as it can enhance the quality of life through its applications in various fields like agriculture and the food system. Around the world it has become the future of any nation.

But we must be very careful with any new technology to be introduced about its possible unforeseen related risks that may come through its positive potential. However, it is also critical for the future of a nation to produce a trained future workforce in nanotechnology. In this process, to inform the public at large about its advantages is the first step, which will result in tremendous increase in the interest and discovery of new applications in all the domains. With this idea in mind, this review has been written.

The theme of the paper is based on the provision of basic knowledge about the applications of nanotechnology in agriculture and their prospects in the near future with reference to the current situation around the world. In this review, some of the potential applications of nanotechnology in agriculture for the welfare of humans and for sustainable environment, challenges and opportunities for developing countries have been identified. Finally, for their solution, collaboration among developed and developing countries, public and private sectors and between research institutions and international organizations have been identified and suggested.

The future of nanotechnology is uncertain due to many reasons, such as negative reaction of the public towards genetically modified crops, lack of many of the requisite skills in public agricultural research organizations for this type of research and ill-equipped and somewhat hesitant regulatory structures to deal with these new technologies. There is a dire need to tear down the sharp boundary present between the social and natural sciences and if we succeed in discarding this boundary, we may be able to develop a more desirable and more democratic sociotechnical future.

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